June 1, 1995 CD-95-09 (LDV/LDT/SM/ICI/LIMO)

Dear Manufacturer,

Subject: MPG Calculations for Certification Vehicles Tested on California Phase 2 Gasoline

The purpose of this letter is to provide manufacturers with EPA's recommended method for calculating fuel economy (mpg) values for vehicles tested on California phase 2 gasoline. The method contained in Enclosure I may optionally be used to calculate fuel economy values for certification or fuel economy vehicles tested on California phase 2 gasoline, in lieu of retesting vehicles using EPA test fuel. This method is based on the method proposed by AAMA/AIAM in response to EPA guidance letter CD-94-16, August 5, 1994. At this time, EPA is approving this method for 1995 model year CAFE testing and 1996 model year fuel economy label testing, only. For reasons explained below, we intend to revisit the issue in December, 1995.

Basis for Approval

The Agency intends to allow the use of this data under the data substitution policy outlined in Advisory Circular 83A, paragraph E.2.a. Data submitted by AAMA/AIAM from 69 phase 2 city tests and 39 phase 2 highway tests showed that this method understates fuel economy by approximately 1.4%, on average, as compared to the same vehicle tested on Indolene. For this reason, and because manufacturers retain the right to retest California certification vehicles using EPA test fuel, we believe that this policy can be adopted without formal rulemaking.

Changes from the Method Proposed by AAMA/AIAM

The method contained in Enclosure I contains several minor changes from the method proposed by AAMA/AIAM in their February 10, 1995 letter to EPA. First, we have added a method of determining fuel properties where the gasoline fuel properties are determined before blending with MTBE, similar to the method proposed in manufacturer guidance letter CD-94-16. We believe that this method is equivalent to the AAMA/AIAM method, will result in the same mpg values as the AAMA/AIAM method, and may be useful for some fuel suppliers and manufacturers.

Second, the heating value of MTBE used in the calculations is changed from 15,140 Btu/lb to 15,100 Btu/lb. This change reflects the latest available information from Arco and the American Petroleum Institute. Third, the mass fraction of MTBE used in the AAMA/AIAM method is determined by direct measurement using ASTM 4815-94, rather than the calculation method proposed by AAMA/AIAM. The mass fraction of gasoline is then calculated, knowing the mass fraction of MTBE.

Fourth, an HC correction factor, [1.03 x HC], has been added to AAMA/AIAM's proposed mpg equation. The basis for this correction factor, as explained in my August 5, 1994 letter (CD-94-16) is to compensate for the underestimation of the FID when measuring oxygenated hydrocarbon compounds. The magnitude of the correction factor has been reduced from 1.1 (in EPA's draft proposal contained in CD-94-16) to 1.03 based on data submitted in AAMA/AIAM letter dated February 10, 1995. Although we have some concerns about the data submitted in support of a 1.03 correction factor, we believe that the 1.03 factor is acceptable for 1995MY CAFE and 1996MY fuel economy label testing, especially in light of its *de minimis* impact on the calculation.

Fifth, the hydrocarbon term used in the mpg equation has been changed from "NMHC + CH_4" (CARB's method) to "HC" (EPA's current method of measuring total HC by FID). Although the HC term has only a minor effect on the mpg calculations, the Agency prefers to use FID total HC emission value for consistency with current EPA emissions and fuel economy regulations. In addition, CARB uses two methods of measuring NMHC values. For Tier 0 and Tier 1 vehicles, CARB NMHC is based on FID total HC minus CH_4 emissions. However for TLEVs, LEVs, and ULEVs, the CARB NMHC emissions are based on FID total HC (calculated using an r factor to account for the FID response rate to CH_4) minus CH_4. Therefore, for simplicity and consistency with past EPA precedent, we believe that it is more appropriate to use the FID total HC value in the mpg equation.

Dilution Factor (DF) Calculation Method

For the city test, the method contained in Enclosure I uses the CARB equation for calculating the dilution factor (DF), in response to comments from Toyota, Nissan and AAMA/AIAM. [The CARB DF equation uses NMHC + CH_4 emissions, while the current EPA DF equation uses total HC emissions, as measured by FID.] We concur with Toyota, Nissan and AAMA/AIAM comments, in the interest of harmonizing CARB emission and EPA fuel economy calculations.

However, for the highway test, the method contained in Enclosure I uses EPA's current DF equation (using total HC emissions). EPA, AAMA, and AIAM believe that this DF equation is appropriate because

1) CARB does not require CH_4 emissions to be measured on the highway test; 2) the difference in the two DF equations has essentially no impact on the mpg calculation; and 3) it reduces the test burden (by not requiring CH_4 emissions to be measured on the highway test).

Timing and Request for Additional Data

As previously stated, EPA is approving this method for 1995 model year CAFE testing and 1996 model year fuel economy label testing only, or until the issue is revisited. We intend to revisit the issue later this year, at which time we intend to evaluate the appropriateness of the 1.03 HC factor; the ASTM procedures used to determine the fuel properties (including methods to allow direct measurement of the net heating value and the carbon weight percent for oxygenated fuels); and the use of the 0.6 R factor. To help with our evaluation of the method contained in Enclosure I and to develop a data base for a possible future rulemaking, we request that the members of AAMA, AIAM, and Mercedes Benz collectively submit additional fuel economy data on 1996 certification vehicles. We believe that many manufacturers will be certifying 50-state vehicles in 1996, which will require certification tests on both EPA and California test fuel. We request that a summary of this data, plus emissions data to evaluate the 1.03 HC factor and the 0.6 R factor be submitted by December 1, 1995, if possible.

To reach a conclusion regarding the appropriate R factor for phase 2 testing, EPA would need city and highway tests on both EPA and CARB test fuel for a minimum of 75 to 100 50-state vehicles. To the extent possible, we request that during the certification process manufacturers attempt to minimize the driver, dynamometer, and test procedure variables, within the restraints of EPA regulations and policy. For example, manufacturers should test these vehicles on the same dynamometer, using the same driver, and the same method of canister preconditioning, if possible. We also request that the final report separates unbias data from bias data, e.g. phase 2 data which is retested using EPA (Indolene) test fuel after the phase 2 mpg came in lower than expected. Additionally we request that the mpg values for the phase 2 tests be calculated using both the mpg equations contained in Enclosure I (the volumetric mpg equation and the corrected mpg equation). We also request the submission of the fuel property data. This will allow EPA to build a data base to evaluate the mpg effects of using phase 2 gasoline and to build a data base to investigate the possibility of revising the R factor for phase 2 fuel. EPA welcomes the suggestions of AAMA and AIAM on how best to perform this additional testing.

ASTM Procedures Used to Determine Fuel Properties

Manufacturers should use the most current version of the appropriate ASTM procedure to determine the fuel properties of the phase 2 fuel. Fuel sampling should be performed in accordance with the provisions of 40 CFR 600.113(c); i.e. on a monthly basis.

The method contained in Enclosure I specifies the use of ASTM D1319 to determine the aromatic content of the phase 2 blend. However, the CARB is currently in the process of adopting ASTM D5580 to determine the aromatic content of phase 2 fuel. If adopted, EPA will consider ASTM D5580 as an acceptable alternative for measuring aromatic content of the phase 2 fuel, unless EPA concludes that ASTM D5580 should not be used, based on data from AAMA, AIAM or other interested parties.

EPA, on the other hand, has much experience measuring the aromatic content of Federal reformulated gasoline using the method contained in 40 CFR 80.46(g), and does not currently have the equipment necessary to perform ASTM D5580. Therefore, EPA intends to use the method contained in 40 CFR 80.46(g) in lieu of ASTM D1319 and ASTM D5580 (if adopted by CARB) unless AAMA, AIAM, CARB, or other interested parties present conclusive data that the method contained in 40 CFR 80.46(g) should not be used.

The method contained in Enclosure I specifies the use of ASTM D4815-94 to determine the MTBE content of the phase 2 blend. The EPA has much experience measuring the MBTE content of Federal reformulated gasoline using the method contained in 40 CFR 80.46(f), and does not currently have the equipment necessary to perform ASTM D4815. Therefore, EPA intends to use the method contained in 40 CFR 80.46(f) in lieu of ASTM D4815 unless AAMA, AIAM, CARB, or other interested parties present data that this method should not be used.

By allowing the use of these fuel sampling and testing methods to determine the fuel properties of California phase 2 fuel, EPA does not imply that they should be used (or considered for use) to demonstrate compliance with the Federal reformulated gasoline, and vapor pressure regulations.

EPA Data Base & Data Reporting Requirements

EPA Test Data: EPA does not intend to recalculate the mpg values of 1995 and 1996 vehicles previously tested at EPA using phase 2 gasoline. These vehicles were confirmatory tested for emission purposes only, and the EPA test data was not intended to be used for fuel economy purposes. Consequently, this previous EPA phase 2 data should not be used for 1995 CAFE or 1996 label calculations (and manufacturer phase 2 data, EPA Indolene data, or manufacturer

Indolene data should be used). For future EPA phase 2 emission tests, the fuel economy values for city and highway tests will be calculated according to the method contained in Enclosure I, paragraph (e). Please note that EPA intends to perform any future 1995 CAFE testing using EPA (Indolene) test fuel.

In the summer of 1996, the EPA will change over from the MTS data base (supported by Wayne State University) to a new in-house data base system. When this new system becomes operational, EPA intends to report two fuel economy values; the corrected mpg value, and an uncorrected (volumetric) mpg value. The uncorrected mpg value will be reported for information purposes only.

Manufacturer's Test Data: EPA does not intend to revise the 1995 data base. Therefore, any previously submitted Phase 2 fuel economy data which will be used for 1995 CAFE calculations should be resubmitted to the EPA data base as type 32 (analytical) data. If the fuel properties or the corrected mpg value cannot be determined according the method contained in Enclosure I, the data should not be used for 1995 CAFE calculations. For 1996 manufacturers test data, the EPA data base will be revised to calculate the mpg values of vehicles tested on phase 2 gasoline according to the method contained in Enclosure I, paragraph (e).

EPA Test Requests: Manufacturers should clearly indicate that phase 2 test fuel was used, the type of canister preconditioning used, and whether or not the fuel economy will be used for fuel economy purposes. If not used for fuel economy purposes, the vehicle should be retested using EPA (Indolene) test fuel and another test request submitted to EPA.

If you have any questions about this letter, please contact Mr. Dave Good on (313) 668-4450.

Sincerely,

Robert E. Maxwell, Director
Certification Division
Office of Mobile Sources

Enclosure

c:\$docs\1fe\ph-2\ph-2calc.595 or g:\cpb\team2\good\ph-2calc.695

Enclosure I

EPA Recommended Procedure For Calculating Fuel Economy (MPG) Values For Vehicles Tested On California Phase 2 Gasoline

The following procedure is intended to be used to determine the approximate fuel economy (mpg) values for vehicles tested on CARB Phase 2 gasoline, since exhaust hydrocarbon emissions are based on FID total HC measurements, only.

(a) Calculate the weighted grams/mile values for the city fuel economy test for HC, CO, and CO_2 as specified in §86.144-94, except that the dilution factor shall be calculated as follows:

$$\text{Dilution Factor} = \frac{100 * (x)/(x + y/2 + 3.76(x + y/4 - z/2))}{CO_{2e} + (NMHC_e + CH_{4e} + CO_e) * 10^{-4}}$$

where:
$NMHC_e$ = CARB method of measuring NMHC, in effect on 4/26/95.

Fuel composition is $C_xH_yO_z$ as measured for the fuel used.

Measure and record the test fuel properties as specified in paragraph (c) below.

(b)(1) Calculate the mass values for the highway fuel economy test for HC, CO, and CO_2, as specified in §86.144-94(b), except that the dilution factor shall be calculated as follows:

$$\text{Dilution Factor} = \frac{100 * (x)/(x + y/2 + 3.76(x + y/4 - z/2))}{CO_{2e} + (HC_e + CO_e) * 10^{-4}}$$

where:
Fuel composition is $C_xH_yO_z$ as measured for the fuel used.

Measure and record the test fuel properties as specified in paragraph (c) below.

(2) Calculate the grams/mile values for the highway fuel economy test for HC, CO, and CO_2, by dividing the mass values obtained in paragraph (b)(1) of this section, by the actual distance traveled, measured in miles, as specified in §86.135-90(h).

(c) Phase 2 test fuel shall be analyzed to determine the specific gravity (SG); the carbon weight fraction (CWF); and the net heating value (NHV) using the method contained in paragraph (c)(1) or (c)(2). Method (c)(1) should be used if the gasoline fuel properties can be determined prior to blending with MTBE.

Method (c)(2) should be used if the gasoline properties cannot been determined prior to blending with MTBE, e.g. when different batches of phase 2 fuel are mixed in a single storage tank.

(1) Determine the SG, CWF, and the NHV of the phase 2 blend as follows:

(i) ***MTBE Content:*** Determine the MTBE content during the blending process by measuring the volume of MTBE and the volume of gasoline, measured to 0.1 gallon or to 0.1 liter. Calculate the volume fraction of MTBE and volume fraction of gasoline in the phase 2 blend, as follows:

$$VF_{MTBE} = \frac{\text{volume of MTBE}}{\text{volume of MTBE + volume of gasoline}}$$

$$VF_{gas} = \frac{\text{volume of gasoline}}{\text{volume of MTBE + volume of gasoline}}$$

where: VF_{MTBE} = Volume fraction MTBE;
VF_{gas} = Volume fraction gasoline.

(ii) ***Specific Gravity:*** Determine the SG of the phase 2 blend using either:

(A) ASTM D1298 or D4052 for the blend, or

(B) ASTM D1298 or D4052 for the gasoline fuel component and the theoretical specific gravity of the MTBE fuel component; and combining as follows:

$$SG_{blend} = SG_{gas} \times VF_{gas} + .7460 \times VF_{MTBE}$$

where:
SG_{gas} = Specific gravity of gasoline per ASTM D1298 or D4052;
.7460 = Theoretical specific gravity of MTBE, ref. ASTM D4815;
VF_{MTBE} = Volume fraction MTBE determined in paragraph (c)(1)(i);
VF_{gas} = Volume fract. gasoline determined in paragraph (c)(1)(i).

(iii) ***Carbon Weight Fraction:*** Determine the CWF of the Phase 2 blend using the following equation:

$$CWF_{blend} = CWF_{gas} \times MF_{gas} + 0.6813 \times MF_{mtbe}$$

where:
CWF_{gas} = Carbon weight fraction of gasoline portion of blend
= $[100-(.06317G - .041089A + .000072135AV + .00005684GV - .0004960GA + 10.56)-S_{gas}]/100$ similar to ASTM D 3343;

where:
G =API Gravity per ASTM D1298 or D4052;

A =Volume Percent Aromatic Content per ASTM D1319;
V =Average volatility = $(T_{10}+T_{50}+T_{90})/3$ per ASTM D86;
S_{gas}=Sulfur mass percent per ASTM D3120 or D2622;

0.6813 = Carbon weight fraction of MTBE;

$$MF_{gas} = \text{Mass fraction gasoline} = \frac{(VF_{gas} x SG_{gas})}{(VF_{gas} x SG_{gas} + .7460 x VF_{MTBE})}$$

$$MF_{mtbe} = \text{Mass fraction MTBE} = \frac{(.7460 x VF_{MTBE})}{(VF_{gas} x SG_{gas} + .7460 x VF_{MTBE})}$$

where:
VF_{MTBE} = Volume fraction MTBE determined in (c)(1)(i) above;
VF_{gas} = Volume fract. gasoline determined in (c)(1)(i) above;
SG_{gas}= Specific gravity of gasoline per ASTM D1298 or D4052;
.7460 = the theoretical specific gravity of MTBE.

(iv) ***Net Heating Value:*** Determine the NHV of the Phase 2 blend using the following equation:

$$NHV_{blend} = NHV_{gas} \times MF_{gas} + 15{,}100 \times MF_{mtbe}$$

where:
NHV_{gas} = Net Heating Value of gasoline portion of blend
= $(16.24G-3.007A+.01714GV-.2983AG+.00053AGV+17685) \times (1-.01S_{gas}) + 43.7S_{gas}$ per ASTM D3338
where:
G, A, V & S_{gas} were determined in parag. (c)(1)(iii);

15,100 = Mass lower heating value of MTBE in Btu/lb.
MF_{gas}= Mass fraction gasoline determined in (c)(1)(iii) above;
MF_{mtbe}= Mass fraction MTBE determined in (c)(1)(iii) above.

(c)(2) Optionally, the SG, CWF, and the NHV of the phase 2 blend may be determined as follows:

(i) ***MTBE Content:*** Measure and determine the MTBE content and mass fraction of MTBE in the phase 2 blend using ASTM D4815. Calculate the volume fraction and mass fraction of the gasoline fuel component of the phase 2 blend as follows:

VF_{gas}= Volume fraction gasoline = $(1-VF_{mtbe})$
MF_{gas}= Mass fraction gasoline = $(1-MF_{mtbe})$

where:
VF_{mtbe} = Volume fraction of MTBE determined per ASTM D4815;
MF_{mtbe} = Mass fraction of MTBE determined per ASTM D4815;

(ii) ***Specific Gravity:*** Determine the SG of the phase 2 blend

and the gasoline fuel component of the phase 2 blend as follows:

(A) Measure the SG of the blend per ASTM D1298 or D4052;

(B) Determine the SG of the gasoline fuel component as follows:

$$SG_{gas} = \frac{SG_{blend} - .7460 \times VF_{mtbe}}{VF_{gas}}$$

where:

SG_{blend} = Specific gravity of the blend per ASTM D1298 or D4052;

.7460 = Theoretical specific gravity of MTBE, ref. ASTM D4815;

VF_{mtbe} = Volume fraction of MTBE determined in (c)(2)(i) above;

VF_{gas} = Volume fraction of gasoline determined in (c)(2)(i) above;

(iii) ***Carbon Weight Fraction:*** Determine the CWF of the Phase 2 blend using the following equation:

$$CWF_{blend} = CWF_{gas} \times MF_{gas} + 0.6813 \times MF_{mtbe}$$

where:

CWF_{gas} = Carbon weight fraction of gasoline portion of blend

= [100-(.06317G -.041089A +.000072135AV +.00005684GV - .0004960GA + 10.56)-S_{gas}]/100 similar to ASTM D 3343;

where:

G = API Gravity of the gasoline portion of the blend, calculated per ASTM D1298, using the value of SG_{gas} determined in paragraph (c)(ii), above;

A = Volume Percent Aromatic Content of the gasoline portion of the blend, which is assumed to be equal to the Volume Percent Aromatic Content of the blend as measured using ASTM D1319;

V = Average volatility of the gasoline portion of the blend, which is assumed to be equal to the average volatility of the blend = $(T_{10}+T_{50}+T_{90})/3$ as measured by ASTM D86;

$S_{gas}=S_{blend} \times MF_{gas}$

where:

S_{blend}=Sulfur mass percent of the blend as measured using ASTM D3120 or D2622;

MF_{gas}=Mass fraction gasoline determined in paragraph (c)(2)(i);

0.6813 = Carbon weight fraction of MTBE.

MF_{gas}= Mass fraction gasoline determined in paragraph (c)(2)(i);

MF_{mtbe}= Mass fraction MTBE as determined in paragraph (c)(2)(i).

(iv) ***Net Heating Value:*** Determine the NHV of the Phase 2 blend using the following equation:

$$NHV_{blend} = NHV_{gas} \times MF_{gas} + 15{,}100 \times MF_{mtbe}$$

where:
NHV_{gas} = Net Heating Value of gasoline portion of blend
= (16.24G-3.007A+.01714GV-.2983AG+.00053AGV+17685) x (1-.01S_{gas}) + 43.7S_{gas} per ASTM D3338
where:
G, A, V & S_{gas} were determined in parag. (c)(2)(iii);

15,100 = Mass lower heating value of MTBE, in Btu/lb;
MF_{gas}= Mass fraction gasoline determined in paragraph (c)(2)(i);
MF_{mtbe}= Mass fraction MTBE determined in paragraph (c)(2)(i).

(c)(3) With prior approval of the Administrator, manufacturers may use other procedures to determine the specific gravity, carbon weight fraction, and net heating value of the phase 2 fuel, if the manufacturer can show that the procedures are equivalent or superior to the procedures specified in paragraphs (c)(1) and (c)(2).

(d) Calculate the city and highway fuel economy from the grams/mile values for HC, CO, CO_2, and, the test fuel's specific gravity, carbon weight fraction, and net heating value. The emission values (obtained per paragraph (a) or (b) of this section, as applicable) used in each calculation of this section shall be rounded in accordance with §86.094-26(a)(6)(iii). The CO_2 values (obtained per paragraph (a) or (b) of this section, as applicable) used in each calculation of this section shall be rounded to the nearest gram/mile. The specific gravity and the carbon weight fraction (obtained per paragraph (c) of this section) shall be recorded using three places to the right of the decimal point. The net heating value (as obtained in paragraph (c) of this section) shall be recorded to the nearest whole Btu/lb. These numbers shall be rounded in accordance with the "Rounding Off Method" specified in ASTM E 29-67.

(e) For vehicles tested on Phase 2 gasoline, the corrected fuel economy in miles per gallon is to be calculated using the following equation:

$$mpg_{corr} = \frac{(CWF_{blend} \times SG_{blend} \times 5174 \times 10^{4})}{((1.03 \times CWF_{exHC} \times HC)+(.429 \times CO)+(.273 \times CO_2))((0.6 \times SG_{blend} \times NHV_{blend})+5471)}$$

Where:
mpg_{corr} = the "official" EPA mpg value for certification vehicles tested on CARB phase 2 gasoline. Data indicate that this mpg value is partially corrected for the differences in fuel properties between phase 2 test fuel and 1975 EPA test fuel.
CWF_{blend} = Carbon weight fraction of the fuel as determined in paragraph (c)(1) or (c)(2).

SG_{blend} = Specific gravity of the fuel as determined in paragraph (c)(1) or (c)(2).

1.03 = a constant to account for the underestimation of the FID when measuring oxygenated HC compounds.

CWF_{exHC} = Carbon weight fraction of exhaust hydrocarbons which is assumed to be equal to CWF_{blend} as determined in paragraph (c)(1) or (c)(2).

NHV_{blend} = The net heating value of the fuel as determined in paragraph (c)(1) or (c)(2).

HC = Grams/mile HC as obtained in paragraph (d).

CO = Grams/mile CO as obtained in paragraph (d).

CO_2=Grams/mile CO_2 as obtained in paragraph (d).

(f) For vehicles tested on Phase 2 gasoline, the uncorrected (volumetric) fuel economy in miles per gallon is to be calculated using the following equation:

$$mpg_{uncorr} = \frac{(CWF_{blend} \times SG_{blend} \times 3781.8)}{(1.03 \times CWF_{exHC} \times HC) + (0.429 \times CO) + (0.273 \times CO_2)}$$

Where:

mpg_{uncorr} = the uncorrected (volumetric) mpg value for certification vehicles tested on CARB phase 2 gasoline.

CWF_{blend} = Carbon weight fraction of the fuel as determined in paragraph (c)(1) or (c)(2).

SG_{blend} = Specific gravity of the fuel as determined in paragraph (c)(1) or (c)(2).

3781.8 = a constant equal to [3785.412 ml/gal x 0.99904 g/ml (the density of water at 60°F, ref. ASTM D 4052)] in g/gal.

1.03 = a constant to account for the underestimation of the FID when measuring oxygenated HC compounds.

CWF_{exHC} = Carbon weight fraction of exhaust hydrocarbons which is assumed to be equal to CWF_{blend} as determined in paragraph (c)(1)(ii) or (c)(2).

HC = Grams/mile HC as obtained in paragraph (d).

CO = Grams/mile CO as obtained in paragraph (d).

CO_2=Grams/mile CO_2 as obtained in paragraph (d).

c:\$docs\1fe\ph-2\ph-2calc.595 or g:\cpb\team2\good\ph-2calc.695